CLAIMS

What is claimed is:

1. A water heater for use in spas, hot tubs, pools, hydrotherapy pools, bath tubs, and similar bodies of water used indoors, outdoors, or both indoors and outdoors, the water heater comprising:

a heating chamber connected in a water flow path for heating water passing therethrough, the heating chamber having an inlet, an outlet, and at least one heating surface; the heating surface having an inner wet surface, and an outer dry surface;

a dielectric layer coupled to the outer dry surface of the at least one heating surface by a binding material formed on the outer dry surface of the heating chamber;

at least one resistor attached to the dielectric layer;

a conductive layer connected to at least a portion of the at least one resistor;

at least one temperature sensor located on or near the water heater;

at least one temperature sensor located on or near the at least one heating surface for sensing temperature;

at least one terminal connected to at least a portion of the conductive layer;

an electronic controller having at least one microprocessor adapted to process signals from a plurality of devices providing water parameter information, the electronic controller connected to the at least one terminal, the at least one temperature sensor, and to a power supply, the electronic controller arranged to control the operation of the water heater and to controllably energize the water heater.

2. The water heater according to claim 1, further comprising a high limit switch connected to the at least one temperature sensor and to the power supply for automatically causing the power to be disconnected from the water heater when the water temperature exceeds a predetermined temperature, the high limit switch requiring a manual reset once the water temperature has dropped below a predetermined temperature to allow power to be reconnected to the water heater.

3. The water heater according to claim 1, further comprising a high limit switch connected to the at least one temperature sensor and to the power supply for automatically causing the power to be disconnected from the water heater when the water temperature exceeds a predetermined temperature, the high limit switch automatically reconnecting the power supply once the water temperature has dropped below a predetermined temperature.

4. The water heater according to claim 1, wherein the at least one temperature sensor comprises:

a first temperature sensor for sensing a first water temperature at a first location on or near the water heater and

a second temperature sensor for sensing a second water temperature at a second location on or near the water heater;

wherein the electronic controller receives temperature values before and after operating the water heater for a given time interval, and determines whether water is present as a result of the difference in the before and after temperature values, the electronic controller configured to turn off the water heater in the absence of water within the heating chamber, and to turn on the water heater upon subsequent receipt of water presence signals from the first and second temperature sensors indicating the presence of water within the pipe.

5. The water heater according to claim 4, wherein the electronic controller deactivates operation of the water heater if the water temperature rate of rise at the first or second temperature sensor location exceeds a specified value.

6. The water heater according to claim 4, further comprising a high limit switch connected to the first and second temperature sensors and to the power supply;

wherein the high limit switch automatically causes power to be disconnected from the water heater when the water temperature exceeds a predetermined temperature, the high limit switch requiring a manual reset once the water temperature has dropped below a predetermined temperature.

7. The water heater according to claim 4, further comprising a high limit switch connected to the first and second temperature sensors and to the power supply;

wherein the high limit switch automatically causes power to be disconnected from the water heater when the water temperature exceeds a predetermined temperature, the high limit switch automatically reconnecting the power supply once the water temperature has dropped below a predetermined temperature.

8. The water heater according to claim 1, further comprising a control panel connected to the electronic controller for inputting user preferences;

wherein the electronic controller activates and deactivates the heater in response to input signals from the temperature sensors and the control panel.

9. The water heater according to claim 1, wherein the at least one heating surface comprises two heating surfaces.

10. The water heater according to claim 1, wherein the at least one heating surface comprises three heating surfaces.

11. The water heater according to claim 1, wherein the at least one heating surface comprises four heating surfaces.

12. The water heater according to claim 1, wherein the at least one heating surface comprises a plurality of heating surfaces corresponding to the number of sides 'n' of a polygonal cross-section of the heating chamber.

13. The water heater according to claim 1, wherein the at least one heating surface comprises a plurality of heating surfaces corresponding to the number 'n' minus one ('n-1'), wherein 'n' corresponds to the number of sides of a polygonal cross-section of the heating chamber.

14. The water heater according to claim 1, wherein the at least one heating surface is stainless steel and the binding material is a chromium oxide coating formed on the outer surface of the heating surface as a result of the stainless steel being heated to a certain temperature.

15. The water heater according to claim 1, wherein the at least one heating surface is made of a non-conductive material thereby eliminating the need for the dielectric layer and the binding material such that the at least one resistor is attached directly onto the at least one heating surface.

16. The water heater according to claim 1, wherein the at least one heating surface is made of a material selected from the group consisting of: copper, copper-nickel alloy, aluminum, aluminum alloys, magnesium, magnesium alloys, titanium, titanium alloys, steel, corrosion resistant varieties of steel, brass, ceramic, glass, or other suitable materials which are resistant to known changes in water chemistry of spas, hot tubs, pools, hydrotherapy pools, bath tubs, and similar bodies of water used indoors, outdoors, or both indoors and outdoors.

17. The water heater according to claim 1, further comprising an inlet pipe and an outlet pipe at the heating chamber inlet and outlet.

18. The water heater according to claim 17, wherein the inlet pipe and outlet pipe have end-flanged couplings to facilitate connection with a water flow system.

19. The water heater according to claim 18, wherein the end-flanged couplings are made of PVC, plastic, or equivalent polymer material.

20. The water heater according to claim 1, further comprising an insulating overcoat covering the dielectric layer, the at least one resistor and the conductive layer.

21. The water heater according to claim 1, wherein the insulating overcoat comprises a glass insulating material.

22. The water heater according to claim 1, wherein the at least one resistor is an electric resistance layer which is a product of depositing an electrically conductive composition onto the binding material.

23. The water heater according to claim 15, wherein the at least one resistor comprises electrically conductive particles dispersed in the binding material.

24. The water heater according to claim 1, wherein the at least one resistor is deposited onto the binding material in a pattern to provide one or more resistors.

25. The water heater according to claim 1, wherein the at least one resistor is deposited onto the binding material by electrostatic spraying with the use of a stencil.

26. The water heater according to claim 1, wherein the at least one resistor is screen - printed onto the binding material in a pattern to provide one or more resistors.

27. The water heater according to claim 1, wherein the dielectric layer, at least one resistor, and conductive layer comprise at least one screen-printed thick film power resistor bonded to the binding material.

28. The water heater according to claim 1, wherein the dimensions and layout of the dielectric layer, at least one resistor, and conductive layer depends on the size and the amount of heat necessary to heat a spa, hot tub, pool, hydrotherapy pool, bath tub, or similar body of water used indoors, outdoors, or both indoors and outdoors, and can be determined in accordance with well-known methods.

29. The water heater according to claim 1, wherein the at least one resistor comprises a plurality of resistors; the at least one terminal comprises a plurality of terminals; and wherein the plurality of resistors, the dielectric layer, the conductive layer, and the plurality of terminals are configured to provide variable operating resistance values.

30. The water heater according to claim 29, wherein the plurality of resistors, the dielectric layer, the conductive layer, and the plurality of terminals are configured to provide separate operating resistance values of 1.5 kilowatts and 4.0 kilowatts, and a combined operating resistance value of 5.5 kilowatts.

31. The water heater according to claim 1, wherein the at least one terminal is coupled to the conductive layer by multi-strand percussion welds.

32. The water heater according to claim 1, wherein the at least one terminal is coupled to the conductive layer by a stud welded onto the conductive layer.

33. The water heater according to claim 1, wherein the at least one temperature sensor is located within the heating chamber.

34. The water heater according to claim 1, wherein the at least one temperature sensor is located within the water flow path on or near the inlet or outlet pipe.

35. The water heater according to claim 1, wherein the at least one temperature sensor comprises two temperature sensor devices located at a first and second separated location on or within the heating chamber.

36. The water heater according to claim 1, wherein the at least one temperature sensor is a mechanical sensor such as a bulb and capillary device.

37. The water heater according to claim 1, further comprising a water presence sensor.

38. The water heater according to claim 1, further comprising a grounding connection coupled to the water heater.

39. A water heater for use in spas, hot tubs, pools, hydrotherapy pools, bath tubs, and similar bodies of water used indoors, outdoors, or both indoors and outdoors, the water heater comprising:

a pipe connected in a water flow path for heating water passing therethrough, the pipe having an outer surface, an inner surface, an inlet, and an outlet;

a dielectric layer attached to at least a portion of the outer surface of the pipe by

a binding material formed on the outer surface of the pipe and configured to bind the at least one dielectric layer to the outer surface of the pipe;

at least one resistor attached to the dielectric layer;

a conductive layer connected to at least a portion of the at least one resistor;

at least one temperature sensor located on or near the pipe for sensing temperature;

at least one terminal connected to at least a portion of the conductive layer;

an electronic controller having at least one microprocessor adapted to process signals from a plurality of devices providing water parameter information, the electronic controller connected to the at least one terminal, the at least one temperature sensor, and to a power supply, the electronic controller arranged to control the operation of the water heater and to controllably energize the water heater.

40. The water heater according to claim 39, further comprising a high limit switch connected to the at least one temperature sensor and to the power supply for automatically causing the power to be disconnected from the water heater when the water temperature exceeds a predetermined temperature, the high limit switch requiring a manual reset once the water temperature has dropped below a predetermined temperature to allow power to be reconnected to the water heater.

41. The water heater according to claim 39, further comprising a high limit switch connected to the at least one temperature sensor and to the power supply for automatically causing the power to be disconnected from the water heater when the water temperature exceeds a predetermined temperature, the high limit switch automatically reconnecting the power supply once the water temperature has dropped below a predetermined temperature.

42. The water heater according to claim 39, wherein the at least one temperature sensor comprises:

a first temperature sensor for sensing a first water temperature at a first location on or near the water heater, and

a second temperature sensor for sensing a second water temperature at a second location on or near the water heater;

wherein the electronic controller receives temperature values before and after operating the water heater for a given time interval, and determines whether water is present as a result of the difference in the before and after temperature values, the electronic controller configured to turn off the water heater in the absence of water within the pipe and turn on the water heater upon subsequent receipt of water presence signals from the first and second temperature sensors indicating the presence of water within the pipe.

43. The water heater according to claim 42, wherein the electronic controller deactivates operation of the water heater if the water temperature rate of rise at the first or second temperature sensor location exceeds a specified value.

44. The water heater according to claim 42, further comprising a high limit switch connected to the first and second temperature sensors and to the power supply;

wherein the high limit switch automatically causes power to be disconnected from the water heater when the water temperature exceeds a predetermined temperature, the high limit switch requiring a manual reset once the water temperature has dropped below a predetermined temperature.

45. The water heater according to claim 42, further comprising a high limit switch connected to the first and second temperature sensors and to the power supply;

wherein the high limit switch automatically causes power to be disconnected from the water heater when the water temperature exceeds a predetermined temperature, the high limit switch automatically reconnecting the power supply once the water temperature has dropped below a predetermined temperature.

46. The water heater according to claim 39, further comprising a control panel connected to the electronic controller for inputting user preferences;

wherein the electronic controller activates and deactivates the heater in response to input signals from the temperature sensors and the control panel.

47. The water heater according to claim 39, wherein the pipe is stainless steel and the binding material is a chromium oxide coating formed on the outer surface of said pipe as a result of the stainless steel being heated to a certain temperature.

48. The water heater according to claim 39, wherein the pipe is made of a non-conductive material thereby eliminating the need for the dielectric layer and the binding material such that the at least one resistor is attached directly onto the pipe.

49. The water heater according to claim 39, wherein the pipe is made of a material selected from the group consisting of: copper, copper-nickel alloy, aluminum, aluminum alloys, magnesium, magnesium alloys, titanium, titanium alloys, steel, corrosion resistant varieties of steel, brass, ceramic, glass, or other suitable materials which are resistant to known changes in water chemistry of spas, hot tubs, pools, hydrotherapy pools, bath tubs, and similar bodies of water used indoors, outdoors, or both indoors and outdoors.

50. The water heater according to claim 39, wherein the pipe is flanged at the inlet and outlet.

51. The water heater according to claim 39, further comprising couplings at the pipe inlet and pipe outlet to facilitate connection with a water flow system.

52. The water heater according to claim 51, wherein the couplings are and made of PVC, plastic, or equivalent polymer material.

53. The water heater according to claim 39, wherein the pipe has an inner diameter of three inches or less.

54. The water heater according to claim 39, wherein the pipe has an inner diameter of one and three-quarters inches (1-3/4").

55. The water heater according to claim 39, wherein the pipe has an inner diameter of two and one-quarter inches (2-1/4").

56. The water heater according to claim 39, further comprising an insulating overcoat covering the dielectric layer, the at least one resistor and the conductive layer.

57. The water heater according to claim 56, wherein the insulating overcoat comprises a glass insulating material.

58. The water heater according to claim 39, wherein the at least one resistor is an electric resistance layer which is a product of depositing an electrically conductive composition onto the binding material.

59. The water heater according to claim 48, wherein the at least one resistor comprises electrically conductive particles dispersed in the binding material.

60. The water heater according to claim 39, wherein the at least one resistor is deposited onto the binding material in a pattern to provide one or more resistors.

61. The water heater according to claim 39, wherein the at least one resistor is deposited onto the binding material by electrostatic spraying with the use of a stencil.

62. The water heater according to claim 39, wherein the at least one resistor is screen - printed onto the binding material in a pattern to provide one or more resistors.

63. The water heater according to claim 39, wherein the dielectric layer, at least one resistor, and conductive layer comprise at least one screen-printed thick film power resistor bonded to the binding material.

64. The water heater according to claim 39, wherein the dimensions and layout of the dielectric layer, at least one resistor, and conductive layer depends on the size and the amount of heat necessary to heat a spa, hot tub, pool, hydrotherapy pool, bath tub, or similar body of water used indoors, outdoors, or both indoors and outdoors, and can be determined in accordance with well-known methods.

65. The water heater according to claim 39, wherein the at least one resistor comprises a plurality of resistors; the at least one terminal comprises a plurality of terminals; and wherein the plurality of resistors, the dielectric layer, the conductive layer, and the plurality of terminals are configured to provide variable operating resistance values.

66. The water heater according to claim 65, wherein the plurality of resistors, the dielectric layer, the conductive layer, and the plurality of terminals are configured to provide separate operating resistance values of 1.5 kilowatts and 4.0 kilowatts, and a combined operating resistance value of 5.5 kilowatts.

67. The water heater according to claim 39, wherein the at least one terminal is coupled to the conductive layer by multi-strand percussion welds.

68. The water heater according to claim 39, wherein the at least one terminal is coupled to the conductive layer by a stud welded onto the conductive layer.

70. The water heater according to claim 39, wherein the at least one temperature sensor is located within the water flow path within or near the pipe.

71. The water heater according to claim 39, wherein the at least one temperature sensor comprises two temperature sensor devices located at a first and second separated location on or within the pipe.

72. The water heater according to claim 39, wherein the at least one temperature sensor is a mechanical sensor such as a bulb and capillary device.

73. The water heater according to claim 39, further comprising a water presence sensor.

74. The water heater according to claim 39, further comprising a grounding connection coupled to the water heater.

75. The water heater according to claim 74, wherein the grounding connection comprises a clamp coupled to the pipe and connected to a ground source.

76. A water heater for use in spas, hot tubs, pools, hydrotherapy pools, bath tubs, and similar bodies of water used indoors, outdoors, or both indoors and outdoors, the water heater comprising:

a pipe connected in a water flow path for heating water passing therethrough, the pipe having an outer surface, an inner surface, an inlet, and an outlet;

a dielectric layer attached to at least a portion of the outer surface of the pipe by

a binding material formed on the outer surface of the pipe and configured to bind the at least one dielectric layer to the outer surface of the pipe;

at least one resistor attached to the dielectric layer;

a conductive layer connected to at least a portion of the at least one resistor;

at least one temperature sensor located on or near the pipe for sensing temperature;

at least one water presence sensor located on or near the pipe for sensing the presence or absence of water within the pipe;

at least one terminal connected to at least a portion of the conductive layer and connected to at least one power controlling device, the at least one power controlling device connected to the at least one temperature sensor, the at least one water presence sensor, and a power supply for controllably energizing the water heater to regulate the temperature of the water heater;

wherein the at least one power controlling device disconnects power to the water heater when the temperature sensed by the at least one temperature sensor exceeds a predetermined temperature and allows power to be reconnected to the water heater once the temperature has dropped below a predetermined temperature;

wherein the at least one power controlling device disconnects power to the water heater when the at least one water presence sensor detects the absence of water within the pipe and allows power to be reconnected to the water heater once the at least one water presence sensor senses water present within the pipe.

77. The water heater according to claim 76, wherein the at least one power controlling device requires a manual reset after power to the water heater has been disconnected.

78. The water heater according to claim 76, wherein the at least one power controlling device automatically reconnects power to the water heater after it has been disconnected.

79. The water heater according to claim 76, wherein the at least one power controlling device has a high limit switch connected to the at least one temperature sensor and to the power supply for automatically causing the power to be disconnected from the water heater when the water temperature exceeds a predetermined temperature, the high limit switch requiring a manual reset once the water temperature has dropped below a predetermined temperature to allow power to be reconnected to the water heater.

80. The water heater according to claim 76, wherein the at least one power controlling device has a high limit switch connected to the at least one temperature sensor and to the power supply for automatically causing the power to be disconnected from the water heater when the water temperature exceeds a predetermined temperature, the high limit switch automatically reconnecting the power supply once the water temperature has dropped below a predetermined temperature.

81. The water heater according to claim 76, wherein the pipe is stainless steel and the binding material is a chromium oxide coating formed on the outer surface of said pipe as a result of the stainless steel being heated to a certain temperature.

82. The water heater according to claim 76, wherein the pipe is made of a non-conductive material thereby eliminating the need for the dielectric layer and the binding material such that the at least one resistor is attached directly onto the pipe.

83. The water heater according to claim 76, wherein the pipe is made of a material selected from the group consisting of: copper, copper-nickel alloy, aluminum, aluminum alloys, magnesium, magnesium alloys, titanium, titanium alloys, steel, corrosion resistant varieties of steel, brass, ceramic, glass, or other suitable materials which are resistant to

known changes in water chemistry of spas, hot tubs, pools, hydrotherapy pools, bath tubs, and similar bodies of water used indoors, outdoors, or both indoors and outdoors.

84. The water heater according to claim 76, wherein the pipe is flanged at the inlet and outlet.

85. The water heater according to claim 76, further comprising couplings at the pipe inlet and pipe outlet to facilitate connection with a water flow system.

86. The water heater according to claim 85, wherein the couplings are made of PVC, plastic, or equivalent polymer material.

87. The water heater according to claim 76, wherein the pipe has an inner diameter of three inches or less.

88. The water heater according to claim 76, wherein the pipe has an inner diameter of one and three-quarters inches (1-3/4").

89. The water heater according to claim 76, wherein the pipe has an inner diameter of two and one-quarter inches (2-1/4").

90. The water heater according to claim 76, further comprising an insulating overcoat covering the dielectric layer, the at least one resistor and the conductive layer.

91. The water heater according to claim 90, wherein the insulating overcoat comprises a glass insulating material.

92. The water heater according to claim 76, wherein the at least one resistor is an electric resistance layer which is a product of depositing an electrically conductive composition onto the binding material.

93. The water heater according to claim 82, wherein the at least one resistor comprises electrically conductive particles dispersed in the binding material.

94. The water heater according to claim 76, wherein the at least one resistor is deposited onto the binding material in a pattern to provide one or more resistors.

95. The water heater according to claim 76, wherein the at least one resistor is deposited onto the binding material by electrostatic spraying with the use of a stencil.

96. The water heater according to claim 76, wherein the at least one resistor is screen - printed onto the binding material in a pattern to provide one or more resistors.

97. The water heater according to claim 76, wherein the dielectric layer, at least one resistor, and conductive layer comprise at least one screen-printed thick film power resistor bonded to the binding material.

98. The water heater according to claim 76 wherein the dimensions and layout of the dielectric layer, at least one resistor, and conductive layer depends on the size and the amount of heat necessary to heat a spa, hot tub, pool, hydrotherapy pool, bath tub, or similar body of water used indoors, outdoors, or both indoors and outdoors, and can be determined in accordance with well-known methods.

99. The water heater according to claim 76, wherein the at least one resistor comprises a plurality of resistors; the at least one terminal comprises a plurality of terminals; and wherein the plurality of resistors, the dielectric layer, the conductive layer, and the plurality of terminals are configured to provide variable operating resistance values.

100. The water heater according to claim 99, wherein the plurality of resistors, the dielectric layer, the conductive layer, and the plurality of terminals are configured to provide separate operating resistance values of 1.5 kilowatts and 4.0 kilowatts, and a combined operating resistance value of 5.5 kilowatts.

101. The water heater according to claim 76, wherein the at least one terminal is coupled to the conductive layer by multi-strand percussion welds.

102. The water heater according to claim 76, wherein the at least one terminal is coupled to the conductive layer by a stud welded onto the conductive layer.

103. The water heater according to claim 76, wherein the at least one temperature sensor is located within the water flow path within or near the pipe.

104. The water heater according to claim 76, wherein the at least one temperature sensor comprises two temperature sensor devices located at a first and second separated location on or within the pipe.

105. The water heater according to claim 76, wherein the at least one temperature sensor is a mechanical sensor such as a bulb and capillary device.

106. The water heater according to claim 76, wherein the water presence sensor is a pressure switch.

107. The water heater according to claim 76, wherein the water presence sensor is a flow meter.

108. The water heater according to claim 76, wherein the water presence sensor is a vacuum switch.

109. The water heater according to claim 76, wherein the water presence sensor comprises a solid state sensing device.

110. The water heater according to claim 76, further comprising a grounding connection coupled to the water heater.

111. The water heater according to claim 110, wherein the grounding connection comprises a clamp coupled to the pipe and connected to a ground source.